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ABBREVIATIONS

ACER	Agency for the Cooperation of Energy Regulators
BRP	Balancing Responsible Party
BSP	Balancing Service Provider
CACM	Capacity allocation and Congestion Management
CWE	Central Western Europe
DER	Distributed Energy Resources
DG	Distributed Generation
DR	Demand Response
DS	Distributed Storage
DSI	Demand-Side Integration
DSM	Demand-Side Management
DSO	Distribution System Operator
EBGL	Electricity Balancing Guideline
EC	European Commission
EE	Energy Efficiency
EED	Energy Efficiency Directive
EMD	Electricity Market Directive
EN	European Standard (developed by European Committee for Standardization)
EV	Electric Vehicle
FCR	Frequency Containment Reserve
FRR	Frequency Restoration Reserve
HVDC	High Voltage Direct Current
ISP	Imbalance Settlement Period
ITRE	European parliament committee on Industry Research and Energy

LBR	Load Balance Responsible
LEC	Local Energy Community
MTU	Market Time Unit
RES	Renewable Energy Source
RTP	Real-time Pricing
SETS	Smart Electric Thermal Storage
SOGL	System Operation Guideline
ToU	Time of Use
TSO	Transmission System Operator
VG	Variable Generation
WLAN	Wireless Local Area Network

1. INTRODUCTION

Power systems have always needed flexibility to maintain their balance. With the rising amount of renewable, variable energy, this requirement becomes even more important [1]. One way of providing flexibility is through demand response of thermal loads. Smart Electric Thermal Storages (SETS) is a thermal storage which is charged with electricity and from the point of view of the power system it is similar to e.g. electric water heating or electric space heating with storage. SETS can only efficiently provide demand response (DR) if technical and non-technical barriers are removed [2]. Non-technical barriers can arise from power markets, tariff regulations, customer acceptance, supplier interest, and taxation. Although the contribution of small-scale DR is increasing, many such barriers still exist in EU countries.

The importance of residential DR has been recognized in EU and specific provisions have been added in e.g. the Electricity Directive (2009/71/EC) and the Energy Efficiency Directive (2012/27/EU) [3]. However, in practise the participation of small DR resources is still in its infancy. The EC's proposed revision of the Electricity Directive and Electricity Regulation, called the Clean energy for all Europeans package, could provide a major step towards including the full participation of DR. Similarly the European Network of Transmission System Operators (ENTSO-E) has prepared network codes which all market operators, transmission system operators and balance service providers must implement.

This report explores the barriers for the type of residential DR provided by SETS in European countries. The main focus is on regulatory barriers. We explore the main changes suggested by the new legislative proposals and network codes and suggest further recommendations.

2. EUROPEAN MARKET REGULATION TRENDS

2.1. Regulatory background

The possibility of DR market participation is dependent on the overall market structure. The power markets integration process of the EU is dependent on mostly the driving force of the European Commission (EC). The main advantage of the EC over the individual member states is its approach to the process from a broader perspective and to be free from national interests [4]. EC has set up the Florence Electricity Regulatory Forum to discuss the creation of the internal electricity market. The Florence Forum decided in November 2008 to establish a Project Coordination Group of experts drawn from the European Commission, regulators, and relevant stakeholders, to develop an EU-wide *Target Model* and a roadmap for the integration of electricity markets. The target model included

- A single European price coupled day-ahead market,
- Implementation of continuous intra-day cross-border trading and
- Pilot projects for the implementation of balancing markets.

EU's Third Legislative Package for the Internal Energy Market in 2009 was introduced to address further barriers to market liberalization. The package included provisions on market-based electricity pricing. Member States were required to implement smart metering where there is a positive cost benefit analysis. The third energy package also established and gave legal mandate to the organization of European transmission system operators ENTSO-E.

EU Parliament's resolution of 13 September 2016, “Towards a new energy market design”, addresses the issue. It notes that the task of integrating a growing share of renewables and prosumers into the electricity markets, but also of improving the mobilisation of demand response and storage, requires a combination of liquid short-term markets and long-term price signals. It calls for time-varying prices that reflect the scarcity or surplus of supply and provide incentives for storage and demand response

The *Energy Efficiency Directive of 2012* (EED) [3] has played an even more central role in driving demand flexibility [5]. In addition to including additional and clear provisions on smart metering and billing based on consumption information, the Directive includes a series of policy measures (Article 15) which require Member States to promote DR. The EED states that Member States shall remove those incentives in transmission and distribution tariffs that might hamper participation of DR, in balancing markets and ancillary services procurement. Furthermore, TSO’s and DSO’s should define technical modalities for participation in balancing, reserve and other system services markets on the basis of the technical requirements of these markets and the capabilities of DR, including the DR provided by aggregators. However, as will be seen below, the implementation of this directive has lagged behind schedule.

2.2. Clean energy for all Europeans - package

Power markets and systems have to adapt to the “4Ds transformation”: decarbonisation, decentralisation, digitisation and democratisation. Decentralisation refers to the proliferation of distributed energy resources. Digitisation shows up in optimized network operation & planning as well as in allowing new market transactions along the power value chain, pulling DR from prosumers. These evolutions are taking place very fast.

On 30 November 2016 the EC published its so-called Clean energy for all Europeans legislative package (a.k.a. Winter Package), which consists of eight proposals to facilitate the transition to a “clean energy economy” and to reform the design and operation of the EU’s electricity market. The Clean Energy Package is setting the direction to the 4Ds transformation – the active customer era [6]. The legislative proposals include:

- revised Internal Electricity Market Directive (EMD) and Electricity Market Regulation,
- revised Energy Efficiency Directive (EED),
- renewed Renewables Directive,
- regulation on Governance of the Energy Union,
- revised Energy Performance of Buildings directive.

From the point of view of energy storages, the category of proposals aimed to bring about a new market design is most relevant. These proposals intend to amend and repeal Directive 2009/72 (Directive on the Internal Market for Electricity) and Regulation 714/2009 (Electricity Market Regulation) and repeal Regulation 713/2009 on the ACER (ACER Regulation). These are referred to as the third package of electricity market as explained above. Generally speaking, the proposal fosters a market based approach. Certain measures are intended to enter into force and to apply as from 1 January 2020, while for others , such as the recast electricity market directive (EMD), no timetable for transposition has yet been indicated.

The package has not yet been finished but is entering trilogue between European Parliament, the Council and the Commission. It is more than likely that the final versions to be eventually adopted by the Council and the European Parliament will look very different from the latest proposals.

In the next paragraphs we will study some provisions of the Clean energy for all Europeans - package from the point of view of energy storages at customer premises.

2.2.1. Smart metering

Smart metering is of key importance in enabling consumer participation in implicit DR. The Third Energy Package already required EU Member States to ensure implementation of intelligent metering systems. This implementation may be conditional on a cost-benefit analysis (CBA). For electricity, there is a target of rolling out at least 80% by 2020, of the positively assessed cases. Most states foresee a rollout of 80% or better by 2020 while some (e.g. Germany, Slovakia and Latvia) have opted for a selective rollout. The proposed EMD keeps the conditionality for roll-out but allows an individual customer to request a smart meter on fair terms. In this case, the customer has to pay for the installation of the meter.

EC recommendation 2012/148/EU [7] provided a rough suggestion for the minimum functional requirements of smart metering systems. In practise, the functionalities of the rolled out meters have greatly varied. The proposed EMD amends the regulation by setting functional requirements for smart metering systems. For example, smart meters shall enable final customers to be metered and settled at the same time resolution as the imbalance period in the national market. The proposed EMD does not set any requirements for load control functionalities of the smart meter.

2.2.2. Dynamic pricing and market entry

Dynamic pricing, along with smart metering, is of key importance in enabling consumer participation in implicit DR. The proposed electricity market directive requires that every final customer is entitled, on request, to a dynamic electricity price contract by his supplier. Dynamic electricity price is also defined to reflect the price at the spot market, including at the day-ahead market at intervals at least equal to the market settlement frequency. This is a significant improvement to current situation where dynamic price contracts are offered only in a few member states. Of course, such contract requires that the customer has a smart meter.

The position of the European Council and the EU parliament on this matter is somewhat divided [8]. According to the Council's opinion consumers should have the possibility to request dynamic price contract from at least one supplier [9]. The European Parliament's Industry, Research and Energy Committee (ITRE), on the other hand, believes that the dynamic price contracts need to be offered by all suppliers. Naturally the ITRE's alternative would introduce more competition into the dynamic contracts and reduce the margins and fixed fees.

Adopting a dynamic price tariff may mean supplier switching. Supplier switching will be made easier by the proposed EMD. The original proposal suggested 3 weeks' maximum limit for supplier switching time but ITRE has suggested only 1 day after 2022. Suppliers will not be allowed to charge any switching-related fees, however, the EU Member States may choose to permit suppliers under certain conditions to charge contract termination fees to customers willingly terminating fixed term supply contracts before their maturity. Household customers shall be entitled to participate in collective switching schemes.

Furthermore, the proposal encourages active customers (those having DR resources) to enter all organized power markets, either individually or through aggregators.

2.2.3. Independent aggregators

Aggregators are deregulated electricity market participants which have the technical means to control distributed energy resources such as loads (in other words DR) or distributed generation and offer the resulting power modulation to organized power markets or power system participants.

Aggregator may be the electricity supplier of the controlled customers, or may be unaffiliated with the supplier, in which case the term independent aggregator is used. The advantages and disadvantages of the independent aggregator model are being disputed. Nordic energy regulators have not seen the whole concept of independent aggregator necessary in Nordic countries [10], while the Smart Energy Demand Coalition [11] strongly supports them. The effects are most likely dependent on the electricity retail market situation in each country. If there is little competition between suppliers and if they are affiliated with generators, independent aggregators can activate more DR. Independent aggregators can target all residential sources of DR within their natural limits; the offering is not limited to SETS.

In the proposed EMD, European Commission requires that every consumer shall have possibility to participate in demand response (DR) and receive remuneration directly or through aggregators. This also introduces a new market participant, an independent aggregator. The independent aggregator is “a market participant that performs aggregation that is not affiliated to its customer’s supplier”. Customers can sign contracts with independent aggregator without asking permission from their supplier. Article 17 of proposed EMD specifically requires that aggregators shall not be required to pay compensation to suppliers. However, in order to ensure that balancing costs and benefits induced by aggregators are fairly assigned to market participants, Member States may exceptionally allow compensation payments between aggregators and balance responsible parties (BRP). These compensation payments shall be subject to approval by the national regulatory authorities. According to ITRE, compensation shall be strictly limited to cover the resulting costs [12]. For example the position of ENTSO-E has been that electricity suppliers must be compensated for the supply costs of power which is transferred to an independent aggregator by DR [13].

Of course, it is not a straightforward task to calculate the cost impact and different national implementations will probably be made. The independent aggregator model is not specified in the detailed level by the directive. Thus there is room left for setting national regulations. In principle, some rules could be set by ENTSO-E but for example the guideline on electricity balancing [14] currently gives plenty of room for national TSO’s in calculating balances and prices. Common independent aggregator model across countries would foster market actor mobility [15]. However, the national markets for aggregation and for DR are in different phases of development. Ref. [15] suggests that e.g. requirements for metering and verification could be harmonized across countries.

2.2.4. Imbalance settlement

Imbalance settlement period (ISP) is the time period which is used by TSO’s to settle the energy imbalances of BRPs. The current ISPs in European countries are shown in Figure 1. According to the proposed regulation [16] the imbalance settlement period shall be 15 minutes in all control areas by 2025. This is also the latest possibility given by the regulation which is currently in force (guideline on electricity balancing, considering the possibility of national regulators to apply for postponement). However, the EU parliament is pushing for a faster implementation by 2021. The decision about the deadline will be made in autumn 2018.

According to EBGL, all TSO’s of synchronous area can apply for an exemption of the harmonization. This is mainly relevant to GB and Ireland.

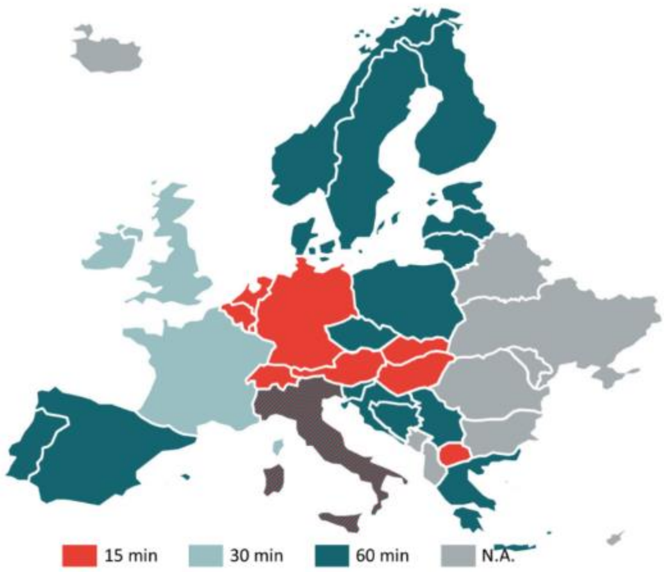

Figure 1: current imbalance settlement periods in European countries. Italy has a 60-minute ISP with the exception of Balancing Service Providers (BSPs) that are required by regulation to have a 15 minute ISP [17].

Shortening the ISP affects SETS and other DR assets via different mechanisms. While the overall need for balancing does not change, the responsibility is shifted more towards power markets. Thus SETS could be used to sell balancing services for the shorter ISP's, which is well within their technical capability. Also for short span trading, such as within the hour, the storage capacity of SETS is not an obstacle. On the other hand, the shorter ISP will reduce the balancing duty of the TSO and therefore the demand for reserves [18]. As noted in Chapter 3, in many cases small-scale DR can also be offered as reserves and this source of income will then be reduced.

According to the proposed regulation [16] market operators shall provide market participants with the opportunity to trade in market time units (MTU) at least as short as the imbalance settlement perod in both day-ahead and intraday markets. Shorterning the ISP immediately affects the intraday markets [18] but plans exists for later adaptation of day-ahead markets . Thus it will be possible to trade power modulation of SETS in 15 min MTU in coming years. ISP harmonization, however, does not imply immediate update of smart meters (which would be costly). E.g. in Nordic countries profiling (using statistical methods for deriving the consumption at ISP resolution) will be used for small consumers. Profiling is not sufficient for activating DR.

2.2.5. Local use of flexibility

DR may contribute to a wide range of different services in the distribution grid, transmission grid and in energy production. Conflicts between different services may also arise. Currently DSO's may not be able to exploit DR. In some countries DSO's do not have access to appropriate tools for procuring DR, while in many countries they are not adequately incentivised through the remuneration schemes in place to do so [19]. This will change in the future: the proposed EMD states that DSO's may use DR (as well as electricity storages or other sources of flexibility) to solve issues in the distribution grid and DSOs shall define the standardized market products for the services to be procured via these flexibilities. ENTSO-E has opposed this proposal. According to ENTSO-E a direct consequence of an exclusive DSO design of flexibility products could be a capture of the offers for the needs of the distribution grids, which would lead to the creation of local markets with low liquidity, barriers for aggregation of flexibilities across different distribution networks, and fragmentation between wholesale and retail markets. This would reduce the value SETS can provide to the electricity system and therefore also their revenue potential.

In the future, the regulation aims to ensure electricity can be co-produced and shared in a local energy community (LEC). LEC will also be guaranteed equal access to participate in to markets. The ITRE committee has amended the proposed EMD [12]:

> Local energy communities are entitled to share electricity from generation assets within the community between its members or shareholders based on market principles, including applying existing or future ICT technologies such as virtual net metering schemes and those based on distributed ledger technologies, as well as through power purchase agreements or peer-to-peer trade arrangements for example.

From the point of view of SETS this can be an important development. For example in a block of flats or among neighbours the excess PV production, produced by one resident or the housing company, could be fed into SETS installed by other residents. The share of self-consumption of locally produced power could be increased. However, no clear statement is made how the distribution fees should be calculated in such case. .

2.3. ENTSO-E network codes

In order to pursue the completion of the internal energy market, ENTSO-E has prepared a number of network codes, which contain detailed requirements for power system participants. The network codes could be called the rulebook for the new power system and market. Originally there were ten codes but they were later merged into eight. These are based on the target market model. The Agency for the Cooperation of Energy Regulators (ACER) was also involved in the process by giving framework guidelines for the preparation of the codes. The process of preparing and accepting the codes lasted 5–6 years. After their acceptance the network codes have become EC regulations. They comprise some 500 pages of text. Furthermore, structures have been put in place between ACER, European Commission and ENTSO-E to amend them if necessary and progressively transition them towards future Clean Energy Package objectives.

Figure 2 shows the different network codes in a timeline relative to the power delivery hour. Here we focus only only three codes, which are most relevant for SETS. These are the network code on Capacity allocation and Congestion Management, guideline on Electricity Balancing, and System Operation guideline. These codes are most relevant for the short-term operation of the power system and demand response.

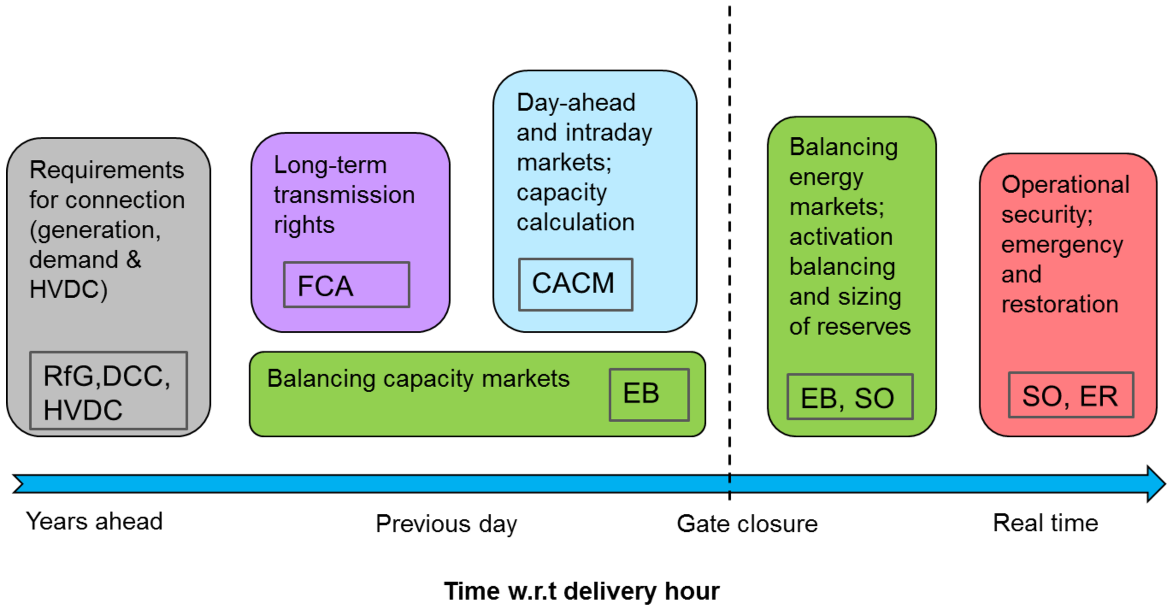

Figure 2: The different ENTSO-E network codes put into context within the timeframe (source ENTSO-E).

2.3.1. *Trading on power markets*

The network code on Capacity allocation and Congestion Management (CACM) concerns for example day-ahead and intra-day power markets. It concerns especially cross-border exchange but directly affects also trading within bidding zones. It encourages competition of power exchanges in the day-ahead market. The continuous intraday market coupling is also covered in the code and the implementation of the intraday trading platform “XBID” is expected to go live in June 2018, after a long development stage. The continous trading has, however, the drawback that cross-zonal (between bidding zones) transmission capacity cannot be properly priced [20]. The CACM regulation states that TSO’s must present a methodology for pricing the cross-zonal capacity. The proposed methodology augments continuous intra-day trading with intra-day auctions. The intra-day auctions gain a better view of the supply-demand situation because they collect a large group of bids into the same process. The auction can thus also place a price on the cross-zonal transmission capacity.

From the point of view of SETS the addition of intra-day auctions is most likely beneficial because it makes participation of small players easier [21]. They benefit from the uniform price auction. The auctions will likely be arranged several times a day, consequently the aggregator still has to maintain a continuous trading desk. The auctions could include the possibility for capability based bids, which are well established for clearing of intraday or balancing/ancillary services platforms in Ireland, Poland, Spain and Italy [21]. Such bids can include the payback effect of SETS – charging the storage back to its normal level after load reduction.

2.3.2. *Balancing markets*

The Electricity Balancing Guideline (EBGL) [14] concerns the specification, trading, pricing and settlement of balancing services, which are needed to constantly match demand and generation in the power system. It is also about allowing new players such as demand response and renewables to take part in this market. From the perspective of a party selling balancing power, the change will require harmonisation of balancing products on the European level. Spefically article 25 of EBGL states that by two years after entry into force of EBGL, all TSOs shall develop a proposal for a list of standard products for frequency restoration reserves (FRR) and replacement reserves (RR). There is no requirement for standard product for frequency containment reserves (FCR). Requirements for FCR have been set in the system operation guideline (SOGL) [22] (former network code on load frequency control and reserves). SOGL includes regulations about the procurement and technical operation of power reserves and their cross-border exchange. Thus SOGL is important for the operation of balancing markets. In many cases SOGL delegates the specific details to individual TSO's and in some cases the regulations concern synchronous areas, as opposed to whole EU.

EBGL sets the common imbalance settlement period in EU to be 15 min by three years after the entry into force of the regulation. However, for compelling reasons national regulators may approve a postponement until January 2025. As mentioned above, the common imbalance settlement period is also covered in the prosed Electricity Regulation of the Clean Energy package.

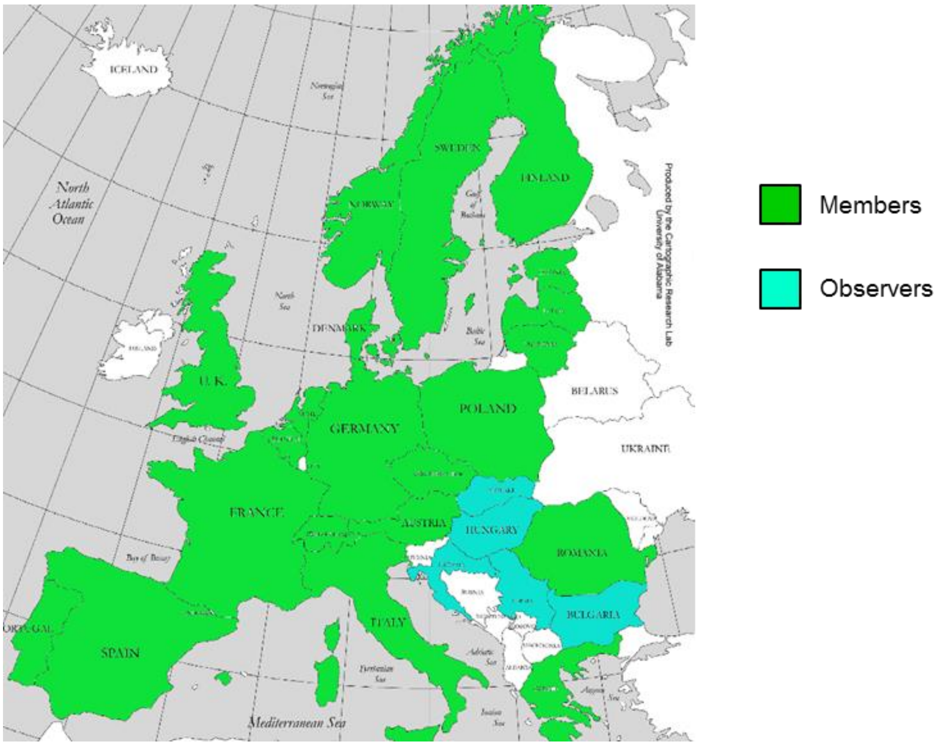

Figure 3: Member and observer countries of the MARI platform (source ENTSO-E).

To support the implementation of the EBGL, several pilot initiatives have been set up for cross-border exchange of balancing services with the standard products required by EBGL[1]. The Manually Activated Reserves Initiative (MARI) started in late 2016 and the purpose is to design and implement a platform for the cross-border exchange of manually activated frequency restoration reserves (mFRR). The platform builds upon national existing platforms by letting balance services providers (BSP) connect to the national platform, while TSO's then forward the balancing offers to the common MARI platform. The balancing energy market will expand, but the national TSO will continue to be the interface. Standard mFRR products are traded on the platform. The specification of standard products is ongoing but some features have been decided. Figure 4 shows the activation profile of the standards product. The balancing service provider (BSP), e.g. an aggregator, must send his offers (gate closure) 25 min before each ISP.

[1] See https://www.entsoe.eu/network_codes/eb/

Activation takes place 7.5 min before the start of ISP and the BSP has 12.5 min to ramp power to full activation.

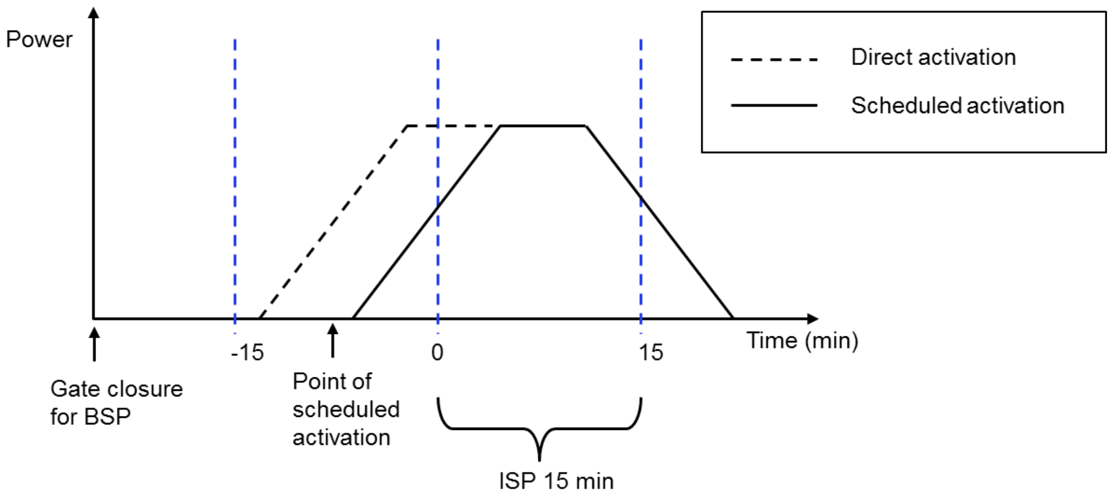

Figure 4: The activation of standardized mFRR products.

Similarly to MARI, the purpose of the PICASSO platform (Platform for the International Coordination of the Automatic frequency restoration process and Stable System Operation) is to enable cross-border trading of automatically activated frequency restoration reserves (aFRR). Standard aFRR products are traded in the platform. The time resolution of offers is that of ISP. BSP must send his offers (gate closure) 25 min before each ISP and has 5 min to ramp power to full activation.

For the slowest reserve category, replacement reserves (RR) the Trans European Replacement Reserves Exchange (TERRE) platform has been set up and the respective standard product has been defined.

The common market for procurement and exchange of Frequency Containment Reserve (FCR cooperation) aims at the integration of balancing markets in the shortest time scale. This regional project currently involves ten TSO's in the central Europe synchronous area, among others the French, German and Benelux TSO's, while the Danish Energinet is also considering to join (as western Denmark belongs to the same synchronous area) [23]. The FCR Cooperation is organised with a TSO-TSO-model, where the FCR is procured through a common merit order list where all TSOs pool the offers they received.

How do the network codes affect the owner of SETS? The standard reserve products can be reached with the performance of SETS, depending of course on the communication system used. Aggregators can more easily operate in several countries because of the standard products (requirements for aggregators, measurement and verification may still vary as explained in the next chapter). This increases competetion between aggregators, which is beneficial from the SETS point of view. Cross-border trading or reserves will be made easier and increase, which can increase demand for DR in some countries and decrease in others.

3. MARKET BARRIERS IN EUROPE

Demand response (DR) can be categorised into two types [1]. First, price-based DR will introduce dynamic pricing in order to let consumers decide when and how they will curtail or shift their demand. Second, incentive-based DR will provide financial incentives for demand shedding independent from the electricity price at that time. Different market mechanisms are needed and different barriers apply for these DR categories. Below the sections 3.1–3.4 mainly deal with explicit DR and section 3.5 with implicit DR.

3.1. Market access of DR

DR has limited value if it cannot be sold and purchased by different power market participants. Different market places for power have been set up in different European countries. Power exchanges operate organized markets for power. Their rules concerning frequency of trading and product time resolution varies across countries. Balancing services are procured at various intervals ahead of real time and activated near real-time by TSO's. Across Europe both the products for balancing services and the arrangements by which they are procured are currently very diverse. This is mainly due to historical reasons as each TSO individually designed their "balancing market" according to national specificities (generation portfolios, significant presence of internal congestions and level of interconnections with foreign markets) [24].

DR can naturally access organized power markets as part of the supplier's portfolio. This is also the way how DR is operated in implicit demand response. In this case the size of the loads does not matter. The same is not true when DR is offered to balancing markets. In that case the resources are subject to a number of requirements or DR (large-scale or aggregated) may not be accepted at all to given balancing market. Below in Figure 2 the situation in certain European countries has been evaluated.

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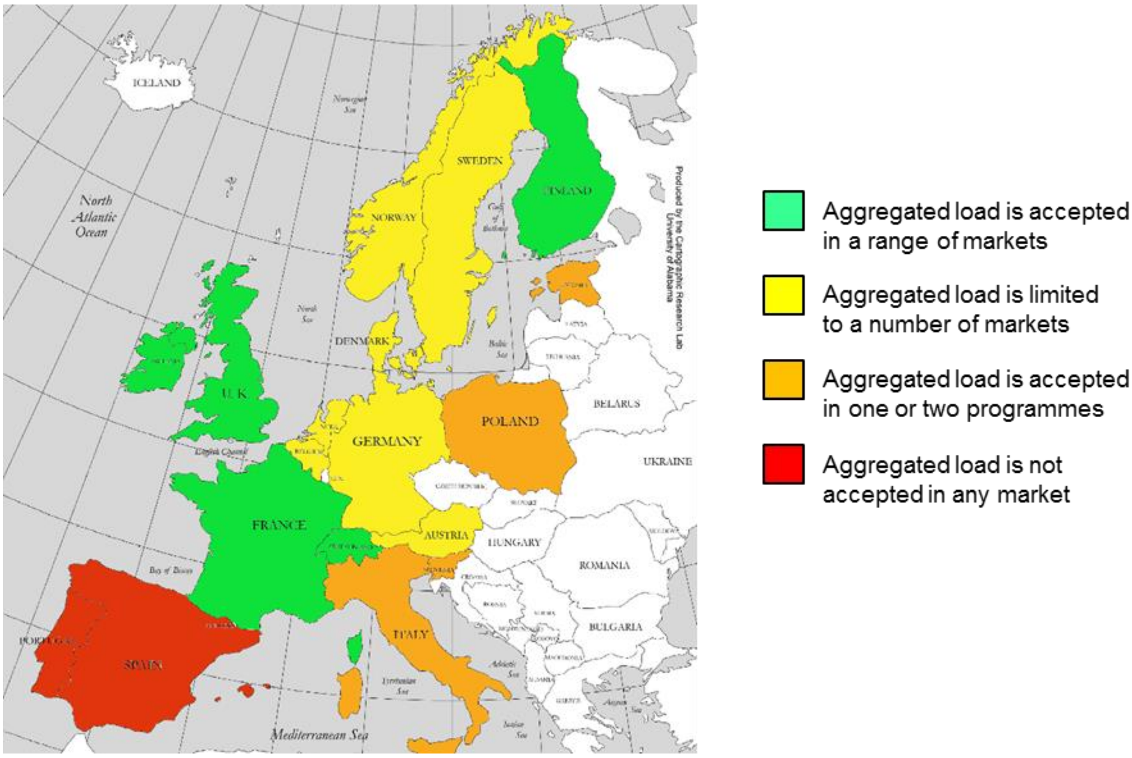

Figure 5: The level of acceptance of aggregated loads in power and balancing markets in Europe [11,25].

Below the situation in a number of countries is explained.

3.1.1. Finland

Aggregated loads can participate multiple markets, including balancing markets and wholesale markets.

3.1.2. France

According to [11] aggregated load can participate multiple markets, including FCR (local market ‘Réglage Primaire de Fréquence’), mFRR (‘Réserves rapides’). FCR participation is through the FCR cooperation project. Aggregated DR can also participate in wholesale markets.

3.1.3. Germany

Aggregated loads can take part in most markets, including the wholesale day-ahead and intraday markets and balancing markets [1,11]. However, DSO may hinder the operation. The DSO legally has to approve consumer participation in the balancing market, and, can limit or prohibit such involvement entirely. While in practice there has not been any unfounded refusal by DSO’s, to date there have been significant delays in some projects caused by the discussions with the grid operators in order to get such approvals [11].

3.1.4. Latvia

The Electricity Market Act provides that aggregators can be operational in Latvia in 2019. By January 1, 2018 Cabinet regulations will be developed that will define the rights and obligations of the aggregators and relations with other members of the electricity system and the market. Taking into account the small market in Latvia, it is expected that already existing electricity traders will act as aggregators. However, it is not known specifically which markets aggregators can enter. However, the local TSO AST has regularly expressed their interest in using DR for balancing services.

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3.2. Market access of independent aggregators

One measure to increase the flexibility in the markets is to enable market actors to aggregate resources more freely than today. Aggregation of small loads into larger blocks for the purposes of power markets is possible in many different ways and different rules have been proposed. One attribute of the aggregation process is the position of the DR aggregator. Aggregation can be done by conventional suppliers and BRPs. Still, new actors including third-party or independent aggregators, have the potential to think outside of the "path of dependency" that may come with conventional business [26]. Independent aggregators may stimulate competition in the field of DR procurement. Traditional suppliers may not be interested in increasing demand flexibility if they are part of a larger company which also acts as generator.

However, considering the added complexity that the introduction of independent aggregators brings, it is not clear whether they can benefit DR markets as whole. While in some countries market rules for independent aggregators have been developed, in other countries their benefits are doubted [10]. The relationship between the independent aggregator and customers suppliers, and the BRPs of the suppliers requires careful analysis.

The current regulatory status for the independent aggregators has been evaluated in a review conducted by Smart Energy Demand Coalition [11]. The status in selected European countries is explained below.

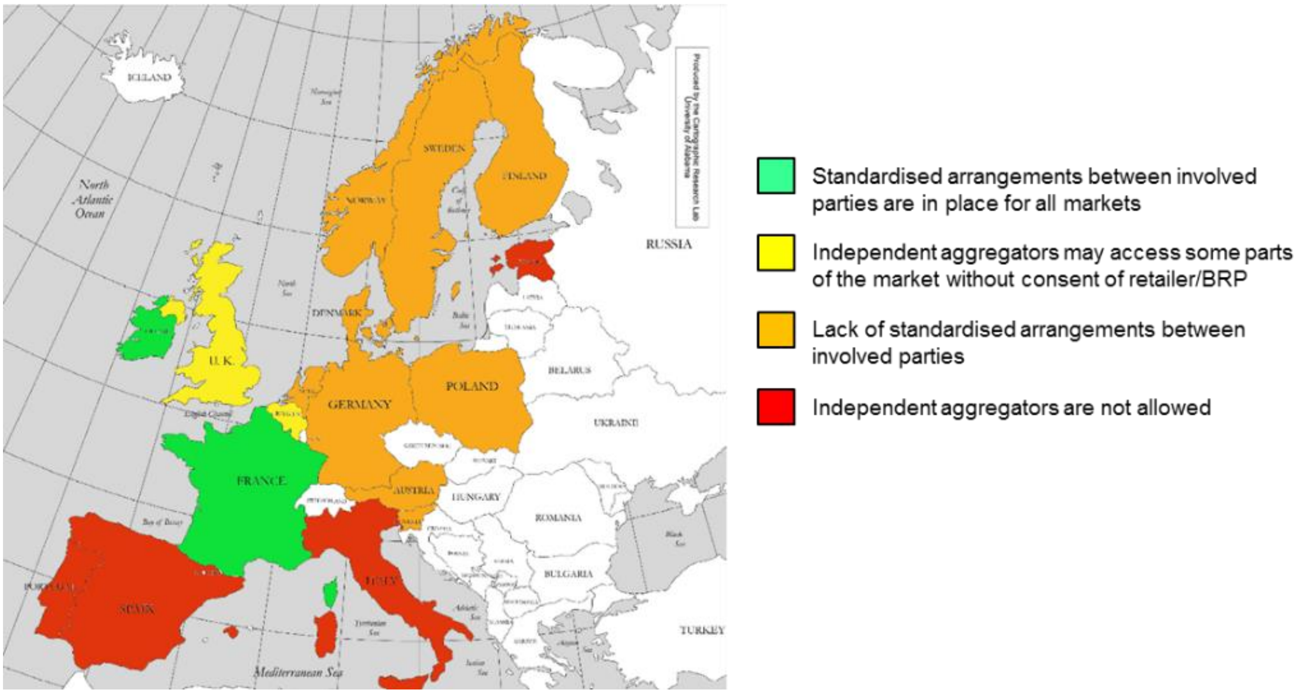

Figure 6: Regulatory status for independent aggregators in European countries. [11]

3.2.1. Austria

Before entering the balancing market, independent aggregators must bilaterally negotiate with each respective BRP concerning consumer data, curtailed volumes and money exchange, which creates difficulties and conflicts of interest between parties [11]. Aggregators must wait sometimes over a year, for this contractual arrangement to be completed.

3.2.2. Finland

Independent aggregators since the beginning of 2017 can participate in the frequency containment disturbance reserve (FCR-D), and since the beginning of 2018 in the frequency containment normal operation reserve (FCR-N). This is because the amount of energy which is exchanged in FCR-D market is fairly small, and consequently the side effects for the suppliers and BRPs are small. Admitting independent aggregators in this market increased DR supply considerably. In FCR-N the symmetricity of the activation reduces the side effects.

The Nordic TSO's are considering the conditions of admittance of independent aggregators into other reserve (balancing) markets [26]. A pilot is currently being carried out in Finland concerning the reimbursement model between aggregator and BRPs in the regulating power market (mFRR). In this pilot TSO calculates the actual delivery and the imbalance caused by reserve activation per BRP based on the measurements and a case specific baseline model. Then TSO removes that imbalance from the BRP with a trade that is priced with the day-ahead market price for the activation hour.

3.2.3. France

Independent aggregators are able to access both wholesale and balancing markets [11]. The NEBEF mechanism (Notification d'Echange de Blocs d'Effacement, 'Notification of Exchange of Blocks of Load Shedding') establishes the transfer of an energy block from the BRP of the consumer's energy provider to the DR service operator and then to the target markets [27]. The contribution of this mechanism is to allow the bid of DR offering on the energy market by an independent aggregator.

Different mechanisms have been established by the law 2014-764 for compensation between the independent aggregator and suppliers. The aggregator can choose a regulated compensation scheme or make a separate contract with the suppliers. In the regulated scheme a financial transfer (in €/MWh) from DR operator to the retailers of the curtailed customers represents the energy component of the energy supply price for the customers participating [11]. The price scale is set by the TSO, and is differentiated for metered and profiled sites.

3.2.4. Great Britain

Independent cannot participate in wholesale markets or the balancing mechanism (a British balancing market with no forward commitments) [11]. They can take part in other balancing markets. Aggregators are not required to ask for permission or to inform the retailer prior to load management and have direct access to consumers.

3.2.5. Germany

Independent aggregators can participate in balancing markets but not wholesale markets because there is not framework in place to define the interactions with the energy retailer and other market parties [11].

Also for balancing markets, regulation has not been issued to encourage the operation of independent aggregators. The independent aggregator should make an agreement with the consumers' BRPs about schedule exchange and payments. This is a particular difficulty because there are no standards for this, and the BRP and retailer often have no interest in working with the aggregator to reach such an agreement. The reason for this is that BRPs/retailers usually see the aggregator as a competitor, someone who is approaching their customer to offer services the BRP/retailer offers, or may intend to offer in future [11]. Naturally the aggregator also needs to sign a contract with the consumers, TSO (in case of balancing services) and consumers' DSO, as noted above.

3.3. Product requirements

Traditionally the generators used to be the only players in the market. Thus originating from the design of the regulatory framework, product barriers exist because market structures are still focused on the characteristics of generators [1]. Product requirements refer to the capabilities of the balancing service provider to provide or consume power in the required way. Product requirements may concern e.g.

- direction and symmetricity (power feed or take or both incorporated in the same offer)
- preparation period,
- ramping rate,
- full activation time,
- minimum and maximum quantity,
- deactivation period,
- minimum and maximum duration of delivery period;
- validity period of the offer.

The service provider may be able to set their own product requirements, which can include e.g.

- minimum duration between the end of deactivation period and the following activation (minimum rest period),
- maximum number of product activations in day or week,
- divisibility,
- links between products such as combined sell and purchase offers.

According to the EBGL standard balancing product should include the possibility to define the minimum duration between the end of deactivation period and the following activation. The implementation of such restrictions, which can be quite useful for SETS, on current balancing markets varies. For example in the Finnish regulating power market (FRR) activation implies automatic unavailability during the next hour if the BSP so wishes.

Below examples of product requirements from selected European countries are listed.

3.3.1. Austria

A few historic regulations remain which are not appropriate for consumers, these treat a single consumer as if they were a large generation unit, for example by requiring them to have a dedicated telephone line to the TSO in order to provide DR [11]. This undermines the position of the aggregator and significantly increases the cost of participating in DR for consumers. Minimum bids size are not a large problem in the balancing market.

3.3.2. Finland

For the day-ahead market so-called flexible bid has been in use for years. It allows an aggregator to capture the highest or lowest hourly price during a day.

In balancing markets product requirements generally are not a large problem. As SETS is capable of very fast response, the activation time is not a problem. For mFRR the minimum bid size (5 MW) presents some restriction for new entrants. The minimum activation time for FCR is currently 15 min (article 156 of SOGL allows between 15 and 30 min), which is not problematic for SETS.

3.3.3. Germany

For the "secondary reserve" (aFRR) response must be able to be sustained for up to 12 hours for and up to 60 hours over the weekend but shortening the requirement has been considered by the regulator [11]. This is a significant barrier for DR. Similarly for "minute reserve" (mFRR) the response must be able to be sustained for 4 hours even though the service is normally only required for much shorter periods [11].

3.3.4. Great Britain

There are several different balancing markets and from the point of view of residential DR the requirements vary by market. The British BSPs have noted the complexity of the balancing service products. This complexity is acting as a barrier to new entrants and technologies, but also making it difficult for existing parties to identify the optimum tendering strategy and hence deliver best value to the end consumer [28]. The TSO will attempt to simplify and make the products transparent. Table 1 lists the current products where demand can participate. Reserves are defined as manually controlled resources and frequency response includes resources with automatic response. As part of the revision of the product structure, specific products such as enhanced frequency response and frequency control by demand management will be discontinued.

Primary, high and secondary frequency response (together "firm frequency response") are tendered each month. The BSP may specify the hours of the day when the offer is valid. Different schedule may be set for working days, Saturdays and Sundays. Still, for providers who could provide frequency response but who cannot forecast or control their availability (including SETS), the timescales of the market represent a barrier to participation [28].

Table 1: Frequency response and reserve services in Great Britain [28,29].

Category	Subcategory	Direction	Notes
Frequency response	primary	positive	activation 10 s, sustained for 20 s
	high	negative	activation 10 s, sustained indefinetely
	secondary	positive	activation 30 s, sustained for 30 min
	enhanced	positive	activation 1 s (to be discontinued)
	demand management	positive	activation 2 s of signal; aggregation possible (to be discontinued)
Reserves	fast reserve	positive	activation 2 min, sustained 15 min, minimum volume 50 MW
	short-term operating reserve	positive	activation 4 h, sustained 2 h; aggregation possible
	demand turn-up	negative	activation within a few hours (agreed case by case)

3.3.5. Belgium

Belgium, as opposed to many other European countries, allows asymmetric bids in the FCR market [1]. This makes DR participation somewhat easier, although aggregation of different types of loads can also allow symmetric bids.

3.4. Measurement and verification

The DR portfolio which delivers certain power product should be monitored in order to make sure that the product is actually delivered as stated in the product requirements. This is crucial from the power system reliability point of view. Measurement and verification can also be considered as part of technical requirements, and is given less attention in this report.

The performance monitoring process occurs at two stages: prequalification stage where a certain DR portfolio is admitted to a market, and continous monitoring of conformance to the product specifications during product delivery. Prequalification for FCR and FRR is required by the ENTSO-E System operation guideline articles 155 and 159 [22]. The exact process is determined by the TSO and may include requirements concerning e.g.

- frequency of power measurements,
- accuracy and speed of local frequency measurement
- power delivery in different grid conditions.

The continuous monitoring may include requirements concerning e.g.

- baseline calculation method;
- Frequency of power measurements and other data provided in near real-time to the TSO.
- Communication protocols.

General requirement for the active power measurements is given in article 154 of SOGL for FCR and article 158 for FRR. Further details are set by each TSO. For example, article 154 states that the active power data of small FCR providing units may be aggregated but SOGL does not state explicitly to which degree an aggregator can use estimation in providing the power measurements. Providing the active power measurements from thousands of units reliably in real time will be costly. Several issues have to be considered. The most important is the communication pathway. High reliability and availability and low latency should be expected [30]. The reliability of the existing internet connections in dwellings for the purpose of ensuring correct operation of power system may be doubted. For example Deconinck [30] rules out mobile connections for this purpose and rates WLAN (which could be used inside a dwelling between SETS device and router) as partially suitable. Of course these technologies have greatly developed during the past ten years. Systems using existing internet infrastructure are also susceptible to malicious attacks.

The experience in the Realvalue project has been that it is difficult to reach near 100 % availibility with connections to individual devices. Reasons include e.g. device malfunctions and unexpected user behavior. Availability of mobile connections to gateways in dwellings was only about 50 % in Spanish trials in the ADDRESS project [31]. While these issues could be mostly solved, pursuing near 100 % availibility increases costs.

Another possiblity would be that the aggregator provides real measurements only from a sample of devices and estimates other data with statistical methods. A sufficiently large sample (still smaller than the total number of devices) ensures that the desired accuracy is obtained. Sampling should take into account the possible differing control of different device groups by the aggregator. For verification, the measurements of all units could be provided to TSO at later time.

3.4.1. Finland

For small consumers the 1 min real-time measurements, required for FCR markets, set requirements on the communication technology and increases costs. The baseline methodology not yet been set.

3.4.2. France

In organized power markets and balancing markets, three groups of baseline methodologies are available [11]:

- Based on values just before and after the DR event,
- historical values either declared by the aggregator or calculated using a statistical approach based on a longer period;
- specific case-by-case method for large portfolios.

In many countries the baseline is negotiated on case-by-case basis (e.g. Great Britain, Austria).

3.5. Availability of dynamic price contracts

Market parties need to be given the right price signals. This is paramount for bringing more flexibility in the system. In short, align markets with physics, recognising renewables increase volatility in grid flows and congestions. From the small customer point of view, dynamic price signals with 15–60 minutes' granularity will soon be reality.

Market acceptance of dynamic pricing can only be achieved if its benefits to both suppliers and consumers can be proved. Suppliers may not have an incentive to offer such tariffs, especially when they are part of larger company which also has a generation wing. Indeed, for integrated generation-supplier companies, high peak prices can result in significant profits, which would be eroded by increased DR [5].

In France a system of ToU tariffs has been in place for more than 40 years [5] and currently ten of the eleven suppliers are offering ToU [32]. In addition, EdF was a forerunner in dynamic tariffs by introducing the Tempo tariff in the early 90's. Tempo tariff is an advanced dynamic (CPP) tariff with peak pricing determined by anticipated system requirement. The tariff is marketed for high use households, such as very large houses, and those with electric heating and full-time occupation, and for small business customers [34]. The tariff comes with six rates of electricity pricing based upon the actual weather on particular days and on hours of use. Each day of the year is colour coded. There are three colours, blue, white and red which correspond to low, medium and high electricity prices. Each day then has a ToU tariff with day-night variation, whose prices levels (and to some extent time zones) are determined by the color of the day. Customers are informed each evening about the colour for the next day. At 8 pm a signal is sent down power lines using a ripple control system. Customers can then control their loads manually or using home automation (especially for heating loads).

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Table 2: Current offering of time-dependent electricity supply tariffs for small consumers in selected European countries [5,32,33].

Country	Real-time	CPP	ToU	notes
Austria	√		√	Real-time supply pricing is being introduced.
Denmark			√	ToU is available for customers with hourly metering
Estonia	√		√	Off-peak tariffs and real time tariffs (for smart metered consumers) are available.
Finland	√		√	Real time tariffs are available from several suppliers.
France		√	√	Selection of available tariff schemes (peak and off-peak, Tempo tariff (CPP tariff) and ToU tariffs.
Germany			√	Mostly day-night ToU
Great Britain			√	Mostly day-night ToU. RTP has been demonstrated.
Ireland			√	ToU offering is mandatory for suppliers. Normally day-night ToU.
Italy			√	
Norway	√			See discussion in the text
Slovenia		√	√	ToU and CCP are applied in Slovenia, and they are established in the law
Spain	√		√	Consumers can choose RTP where smart meter with full telemanagement has been installed
Sweden			√	ToU tariffs are offered to all customers by some grid companies.
Switzerland			√	CPP and RTP not available for small customers

ToU tariffs have also been in place in the UK since the 1970s for smaller consumers [5]. In 2015 around 13 % subscribed to ToU tariffs such as the Economy 7 tariff, which offers a lower supply tariff for 7 hours at night.

“Real-time tariff” is a misnomer because in their most common form prices are set the previous day and not close to real time. We can talk about dynamic hourly tariffs but in some countries 30 min is used as load registering period and in future consumer loads in EU are most conveniently (to match with the imbalance settlement period) measured with 15 min registering period. Real-time tariffs are offered to small customers in relatively few countries, notably Finland, Norway, Spain and Estonia. These are based on hourly consumption. In Norway for small customers that have the possibility for hourly metering (will be possible for all in 2019), hourly real time prices are possible. In France RTP is not available to small customers. The energy ombudsman, Jean Gaubert, has opposed dynamic billing on the basis of the risk which possible high wholesale market prices present especially to vulnerable customers [35].

4. GRID ENVIRONMENT

4.1. Smart meter roll-out

The fundamental requirement for price-based DR and certain types of explicit DR is a smart meter, which provides accurate measurements at high time resolution, and in some cases the ability to control loads. Indeed, several smart meters can be exploited to extract several benefits: improve retail processes, allow distribution system operators to manage power quality and outages, and enable DR and improve energy efficiency through feedback. Implementation of intelligent metering systems, subject to positive cost-benefit evaluation, was already mandated by the Third Energy Package and the EC published a set of recommended minimum functional requirements for the meters [7]. These are based on the work done by CENELEC, CEN and ETSI based on the EC mandate M/441.

In practise the meter functionalities and implementation of the roll-out have greatly varied across European countries [36]. Figure 7 shows the situation of different countries in a two-dimensional plane. The abscissa of the plane measures the legal and regulatory status of smart metering, and the ordinate progress in smart metering implementation. We see that among the depicted countries there is a rather clear relationship between implementation and regulation. There are no examples where the implementation would be driven solely by market signals (the upper left corner in the plane).

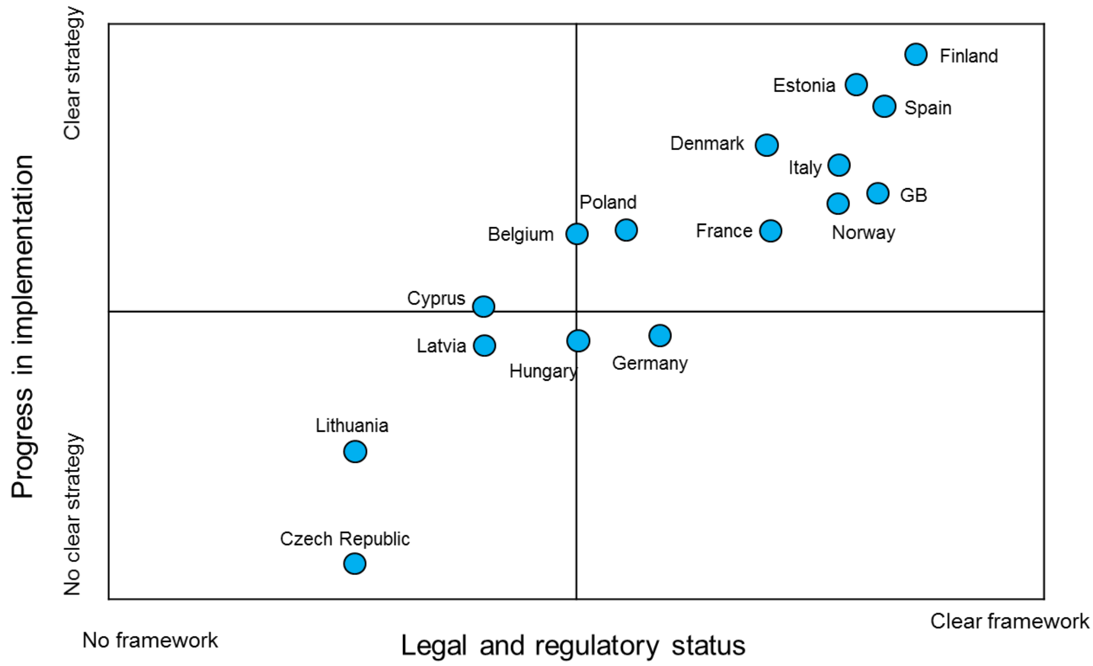

Figure 7: Legal, regulatory and market situation in the European electric smart metering implementing process (progress in September 2016) [33].

4.1.1. Finland

The Government Statute on measurement and settlement of electricity supply (5.2.2009/66) stated that DSO's must provide at least 80 % of customers with hourly interval meters by 2014. In practise nearly

100 % smart meter coverage was reached by 2014. The meters also include remote-controlled relays for load control, normally one for ToU based control and one for other load control.

4.1.2. Great Britain

In Great Britain the government aims to roll out 53 million smart meters to domestic consumers and smaller non-domestic consumers by the end of 2020 [32]. Unlike in many other countries, it is the electricity supplier's responsibility to install the meter. Smart meters are not compulsory and customers can opt out. The meters have the necessary functionality to reflect real-time prices (will store the amount of energy the customer has used in each 30 minute period) and allow either direct consumer responses or automated services via third parties [32].

4.1.3. France

In France the "Linky" smart meter was especially developed for Enedis (former ERDF). In 2021 the coverage should be 90 % [32].

4.1.4. Germany

The cost-benefit analysis for large-scale roll-out by 2020 was negative. Therefore the country has chosen a conditional rollout. In the first step, only large customers with a consumption of over 10,000 kWh have to install a smart meter. From 2020 the rollout scheme includes consumers with annual electricity consumption higher than 2,000 kWh [33].

4.1.5. Norway

The deployment of smart meters to all customers will be completed in Norway by January 2019. After that all customers will have the possibility for hourly metering of their consumption. For customers that have already got a new smart meter installed, hourly metering is not activated for all customers yet. In the beginning the smart meters will be used for monthly meter reading.

4.1.6. Spain

Cost-benefit analysis for large-scale roll-out was carried out but the results are not public. In 2016 Smart meter roll-out was progressing rapidly, with most of the 5 main DSO's reached over 70 % penetration [33].

4.1.7. Latvia

The cost-benefit analysis for large-scale roll-out by 2020 was negative or inconclusive, but smart metering was found to be economically justified for particular groups of customers [33]. The largest DSO is slowly rolling out smart meters.

4.2. Grid tariffs

Distribution grid tariffs form one part of the electricity price which the end-user has to pay and thus affect the optimal use of DR. They may provide more opportunities for DR to reduce grid fees.

Fixed tariff is currently the most common tariff type for small consumers. Static time-of-use (ToU) is a widely used model internationally. The tariff follows a normal grid capacity utilisation profile, so that the tariff is high at normal peak load times. In the Nordic countries, ToU tariffs have been most commonly used in Finland. As for other countries, France, UK and Germany are the most prominent cases [37]. ToU grid tariff can provide some opportunities for SETS but can also interfere with market based operation. In many countries demand charges (based on peak power consumption calculated in various ways) are under discussion [8]. In principle avoiding demand charges can introduce another income source for SETS but they can also disturb offering other services and lead to inefficient use of the grid [38]. Thus careful design of the tariff is necessary.

Below examples of current grid tariffs in several EU countries are listed.

4.2.1. Denmark

DSOs are free to set their own tariffs based on their approved methodology. Demand charges are not allowed at the moment [37]. It is the DSOs' responsibility to adjust revenues in accordance with the revenue cap and/or maximum return, set by the national regulator. In June 2015, the national regulator accepted a new, industry wide tariff model [39]. The model opens up for ToU tariffs for all groups of consumers. Smart meters, which are required for this, have been rolled out to almost all customers.

4.2.2. Spain

The Spanish law 54/1997, 27th of November, of Electric Sector, establishes that electric energy distribution is a regulated activity, subject to regulatory development by the Government of Spain. Grid tariffs are regulated by the state. The grid tariffs are composed of a power term (demand charge) (Tp) and an energy term (Te). In this way, the access cost depends both on the consumer's consumed power and energy. Figure 8 shows the grid tariffs for small customers. The power term exists even for residential customers.

Tarifas BT						
	Colectivo de aplicación	Tp [€/kW año]	Te [€/kWh]			
			Sin DH	Periodo 1	Periodo 2	Periodo 3
2.0 A	Pc ≤ 10kW	38,043426	0,044027	-	-	-
2.0 DHA	Pc ≤ 10kW	38,043426	-	0,062012	0,002215	-
2.0 DHS	Pc ≤ 10kW	38,043426	-	0,062012	0,002879	0,000886
2.1 A	10kW< P≤15kW	44,44471	0,05736	-	-	-
2.1 DHA	10kW< P ≤ 15kW	44,44471	-	0,074568	0,013192	-
2.1 DHS	10kW< P ≤ 15kW	44,44471	-	0,074568	0,017809	0,006596

Figure 8: Regulated grid tariffs in Spain for low-voltage customers. "Periodo1–3" refer to the ToU time zones, which refer to day, night and morning + late evening.

4.2.3. Finland

Residential customers face a flat distribution tariff or ToU tariff with either day-night time zones or winter day and rest of the year time zones. In the preparatory work for the electricity market law (HE 20/2013 vp 54§) and in the decree about metering and clearing of electricity supply (217/2016 chapter 7) it was required that DSO's must provide at least the following distribution tariffs:

- flat tariff,
- ToU tariff with day-night time zones,
- ToU tariff with winter day and rest of the year time zones,
- hourly tariff.

In practise the DSO's do not offer hourly grid tariffs. In the preparatory work for the electricity market law (HE 20/2013 vp 25§) it was required that DSO's cooperate to create uniform hierarchical structure for grid tariffs in different voltage levels. This means that the tariff structures of different DSO's should be compatible. It was not required that the price level of the grid tariffs should be uniform across different

DSO's. There are no other specific regulations about the required grid tariff structure. For example, there are no regulations about how the costs should be allocated to different tariff components. In practise the price levels of different tariff components have varied widely across the approximately 90 different DSO's.

In recent years demand charges for residential customers have also been discussed and studied in several research projects. They were adopted e.g. by Helen sähköverkko DSO in Helsinki region in 2017.

The energy component of the tariff is paid for the delivered energy and thus self-consumption is encouraged.

4.2.4. Austria

Residential customers face a flat tariff. ToU tariffs exist in the monthly level, and thus have little effect on DR. There are major differences in the ToU time zones within the country [40]. Distribution tariffs are paid for the consumed energy and thus self-consumption is encouraged.

4.2.5. Germany

In Germany household customers and SME with less than 100 MWh annual consumption pay only a flat distribution tariff [41]. High growth in DG combined with the very large number of distribution system operators raises critical questions about increasing grid costs, and how the tariffs to recover these costs should be designed and allocated among grid users. In future time-differentiated demand charges (at least for larger customers) or dynamic tariffs tied to market energy prices could be options.

4.2.6. Italy

The network tariff paid by final customers consists of:

- fixed component (euro/customer)
- demand charge component related to capacity (euro/kW)
- variable component related to energy (euro/kWh)

Tariffs are geographically‐uniform; it is a legal requirement that the same network tariff for final customers is applied throughout the country [40]. ToU tariffs are not applied. Residential customers face significant demand charges which encourage them to avoid load variations.

4.2.7. Great Britain

Residential and small SME's pay a flat distribution tariff or ToU tariff with two time zones.

4.2.8. Norway

There is an ongoing discussion about the type of the grid tariff. The grid tariff will be renewed when all customers have hourly metering of their consumption (2019). A hearing round for new regulations was performed in winter 2017-2018. The response from the national regulator will be available during the spring 2018 [42].

4.2.9. Latvia

Residential customers pay a flat distribution tariff or ToU tariff with two time zones .

4.3. Policies for prosumers

According to ITRE wording of the proposed EMD

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Active customers are entitled to generate, store, consume and sell self-generated electricity in all organised markets either individually or through aggregators without being subject to discriminatory or disproportionately burdensome procedures and charges that are not cost reflective.

In order to support deployment of renewable energy sources and distributed generation many EU member states adopted different types of subsidy mechanisms. Here we limit ourselves to photovoltaic (PV) plants because they are the most common type of distributed generation in residential buildings. Mechanisms promoting self-consumption of PV electricity are based on the idea that PV electricity will be used first for local consumption and that all this electricity should not be injected into the grid [43]. Smart thermal storages are introduced into the equation as one way of increasing self-consumption in a flexible manner.

Essentially the mechanisms dictate what benefits prosumers get from self-consumed energy and energy exported to the grid. Figure 9 shows the most important components of a self-consumption scheme. Typically the revenue of self-consumed energy consists of savings in the energy bill. At the same time variable grid fees are saved. Some countries (e.g. Spain) introduce an additional tax that recovers a part of these grid costs [43]. The revenue of exporting PV electricity into the grid varies considerably from one country to another. Many EU countries also dictate that small producers do not have to pay electricity tax for the self-consumed energy [44]. The scheme should also define self-consumption. Essentially it is the energy which is consumed simultaneously with the production. However, some smart meters e.g. in Finland also count production as exported energy if it is connected to a different phase than consumption. When the period during which consumption can be compensated with production is extended, the regime of net metering is entered. Geographical scope refers to the concept of LEC which was already visited in Section 2.2.5.

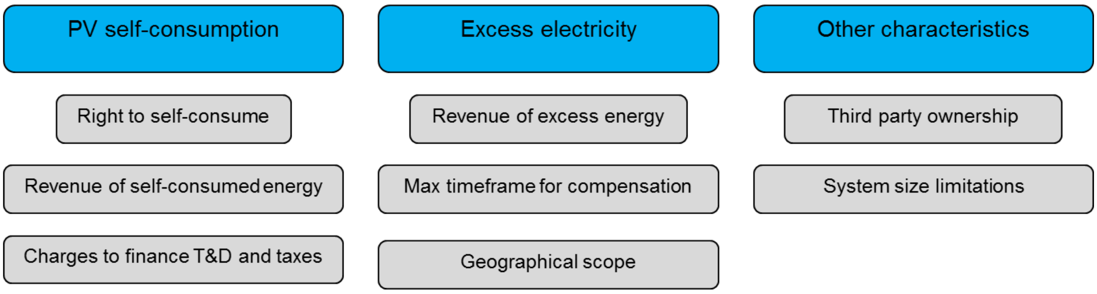

Figure 9: Components of PV self-consumption scheme (adapted from [43]).

SETS is an excellent way to increase self-consumption, though opposing seasonality of space heating and solar irradiation limit the opportunity. Features of self-consumption scheme which decrease the value of exported energy and limit net metering opportunity are beneficial for SETS. In UK for example exported energy receives a special bonus which reduces the incentive for self-consumption.

5. RECOMMENDATIONS FOR OVERCOMING THE BARRIERS

Many regulatory changes concerning residential DR are being carried out in the EU level, including the Clean energy for all Europeans - package and implementation of ENTSO-E network codes. EU drives for market based solutions and for the inclusion of the smart customer and the demand response potential to be found there. Therefore there is little need for new regulations in EU level. The new directives and regulations are hard to improve since their final forms have not emerged yet. However, the implementation of the directives in national legislation and the implementation of network codes by TSO's can be guided to consider residential DR.The following areas of development can be seen where barriers can be reduced:

- Auction periods for balancing markets should accommodate the types of DR which may be difficult to forecast several days ahead.
- Adoption of intra-day auctions in power markets may offer a level playing field for aggregators. The auctions could also include possibility to submit capability based bids, which can better capture the dynamic ability of SETS and other DR.
- Dynamic tariffs should be available for everybody (as dictated by the proposed EMD), and smart meters for all end-users who request one, as the directives hopefully will propose even in their final form. The cost of installing a smart meter is a barrier. End-users in countries. which (based on a cost-benefit-analysis), have come to the conclusion of no mandatory installations, will be at a disadvantage, if they have to also pay for smart meters to be able to use their flexibility on the markets.
- Prequalification can be a laborious process for the aggregator. It may mean that each site must be equipped with power meter which can work with seconds granularity. If the customer portfolio changes, prequalification may be invalidated, depending on the rules set by TSO. For SETS it could be possible to make a prequalificiation for the device, and not for the customer portfolio where SETS has been installed. This approach may not work if there are issues which depend on the specific customer portfolio (e.g. performance of the communication pathway).
- Real-time measurements of consumed power must be provided to the TSO, as stated by the ENTSO-E system operation guideline. For example in Finland they must be sent once a minute from each site. For a large customer portfolio, this may be unnecessary. A sample of customers can likely provide the measured power with adequate accuracy, while the majority of customers could be estimated with statistical models.
- The regulation of local energy communities (LEC) could greatly improve the feasibility of SETS. Often it is not the same people who install DG and SETS and it may be more affordable to install a large amount of DG in one place. Ability to connect the local generation and SETS across apartments and real estates increases their value.
- Baseline methodologies for different customers and applicances should be developed and published. Their number should reflect different customer behavior but should be limited as far as possible.
- When grid tariffs are changed, the regulators should analyze the effects on the ability to provide DR for different markets. Distribution tariffs should not hamper the participation of DR. In some countries there is a tendency to introduce demand charges for residential customers. Most of distribution network costs are not related to distributed energy, but to distribution capacity and network peak loads, which in the future bolsters the use of demand charges:
    - The demand that forms the basis for the demand charges should be measured only at the time window where the network is at strain. If it is in the winter at daytime, it might mean that a PV owner might have higher costs than today, which is fair. PV owners' demand put the same strain on the network as not-owners.
    - Although demand charges will have an adverse effect on most business cases for electric heating, constructed in an intelligent way as described above, end-user SETS would benefit compared to direct resistance heaters.

- The Clean Energy for all Europeans package includes the mandatory introduction of independent aggregators. The aggregator model, including compensation between aggregator and other parties, should be carefully analyzed by national regulators, to produce fair and efficient solution.

6. CONCLUSIONS

This report explored the current barriers for residential DR, such as that provided by SETS. We found out that different barriers exists, such as those of market access, market rules, supplier interest and grid regulation. The situation also varies from country to another. Many changes are currently taking place in the residential DR field. The ENTSO-E grid codes have been finished but their implementation is on-going. At the same time, the EU Clean Energy for all Europeans package is entering final trilogue between European Parliament, the European Council and the Commission. The active consumer is the core concern of the package. The directive proposals belonging to the package do not go to the detail level. Therefore we cannot yet say with certainty what kind of changes it will bring to residential DR. However, we identified topics and more detailed suggestions which could increase the feasibility of demand response offered by residential thermal storages.

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